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The Polyamide Market

DOI: 10.5604/12303666.1215537

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Abstract
This article presents changes that have occurred in recent years on the market for polyamides (PA). Attention is given to the various factors which brought about the changes. Demand and production figures are shown and the biggest players in production and commerce are indicated. The share of polyamides is compared with other polymers, and the demand for polyamide resins from various segments of industry is enumerated. Various figures characterising the market are quoted. While stability is observed in the production segment of classical polyamide fibres, much attention is given to the dynamic growth in the sector of polyamide resins. Impressive changes both in quality and quantity are taking place in the consumption of PA resins in many industry branches: the car industry, electrical and electronic appliances, civil engineering, packaging, and many others. Examples are given in the article of modern solutions and products put on the market as a result of close cooperation between R&D centers, industry and consumers. Most of the information contained herein is concerned with classical polyamides i.e. PA6 and PA66, yet other polyamides like aromatic-, long-chain-, and bio-polyamides are also highlighted.

Key words: *polyamides, market, polyamide fibres, polyamide resin, polyamide engineering plastics, films.*

Introduction

Polyamides have been on the market for nearly 80 years. Fibres made of PA6 and PA66 were the first commercialized polyamide products. The first polyamide fibres made of PA66, called Nylon, appeared on the market in 1938. It was W.H Carothers who invented the process of their production in the laboratories of DuPont de Nemours. At the same time, in Europe, one other polyamide PA6 fibre emerged under the name of Perlon; it was developed by the German company IG Farbenindustrie following P. Schlack's invention concerning the ability of caprolactam to polymerise [1]. Until today, these two polyamides have played a dominant role in production and on the market. From the time of their market debut throughout the forties of the last century, they were first used solely in the production of fibres. However beginning in the 50-ties, there was an ever increasing demand for their use in the resin sector. Presently the largest amount of polyamides is still processed as fibres, but the resin segment is witnessing ever higher rates, which is because polyamide resin can be easily adapted to specific requirements in a broadening span of applications. Classical PA6 and PA66 polymers are in many ways being replaced by new groups of polyamides, like long-chain, aromatic and bio-polyamides. Thanks to their original properties, the new polyamides not only are replacing the classical ones in some applications but are also opening ways to entirely new uses where classical have failed.

Volume of production

PCI Research GmbH, Oberursel, Germany in their reports forecasted a demand for polyamides of over 7.4 million tons for 2016 and for 2020 an increase by 2.3% and 2.7% for PA6 and PA66, respectively [2, 3]. Ceresana Market Intelligence Consulting reported sales in 2014 of PA6 and PA66 polyamides in the amount of 24.4 billion US dollars and predicted an annual increase of 3.1% to reach the value of 31.2 billion US dollars in 2022 [4]. In their report [5] the market research company MarketsandMarkets forecast for polyamide type PA6, PA66, Bio-Based & Specialty, a market value of 43.77 billion US dollars in 2020, with an annual increase of 5.4% in the period of 2015-2020.

Manufacturers and domains of application

Companies which analyse the market for polyamides mention the following concerns and chemical companies as key players on the market: Asahi Kasei Corporation, Arkema S.A., Ascend Performance Materials LLC, BASF SE, EI Du Pont de Nemours and Company, Formosa Chemicals & Fibre (FCFC), Grupa Azoty SA, Honeywell International Inc., Huntsman Corporation, Honeywell International Inc., Invista S.à rl , Koch Industries Inc., Lealea Group, LANXESS AG, Li Heng Chemical Fibre Technologies Limited, Li Peng Enterprise Co. Ltd., Nylstar SA, Radici Group, Rhodia SA Royal DSM NV, Solvay SA, Shenma In-

Wesołowski J, Płachta K. The Polyamide Market.
FIBRES & TEXTILES in Eastern Europe 2016; 24, 6(120):12-18. **DOI:** 10.5604/12303666.1215537

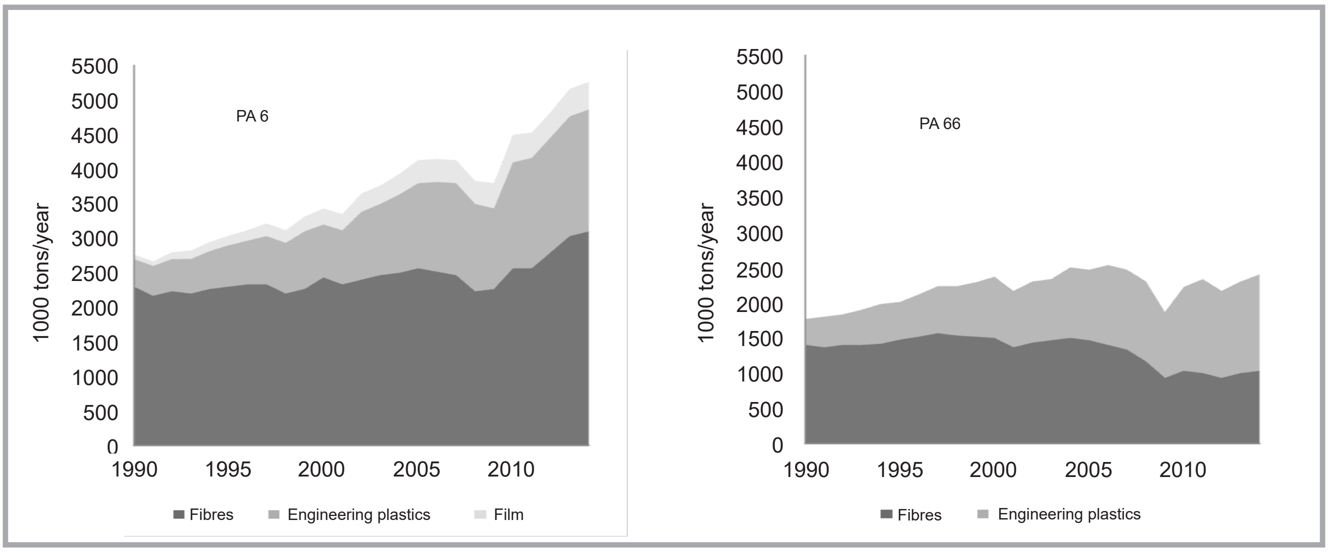

Figure 1. *Consumption of polyamides PA6 and PA66 in 1990 - 2015 in the areas of fibres, engineering plastics and films [8].*

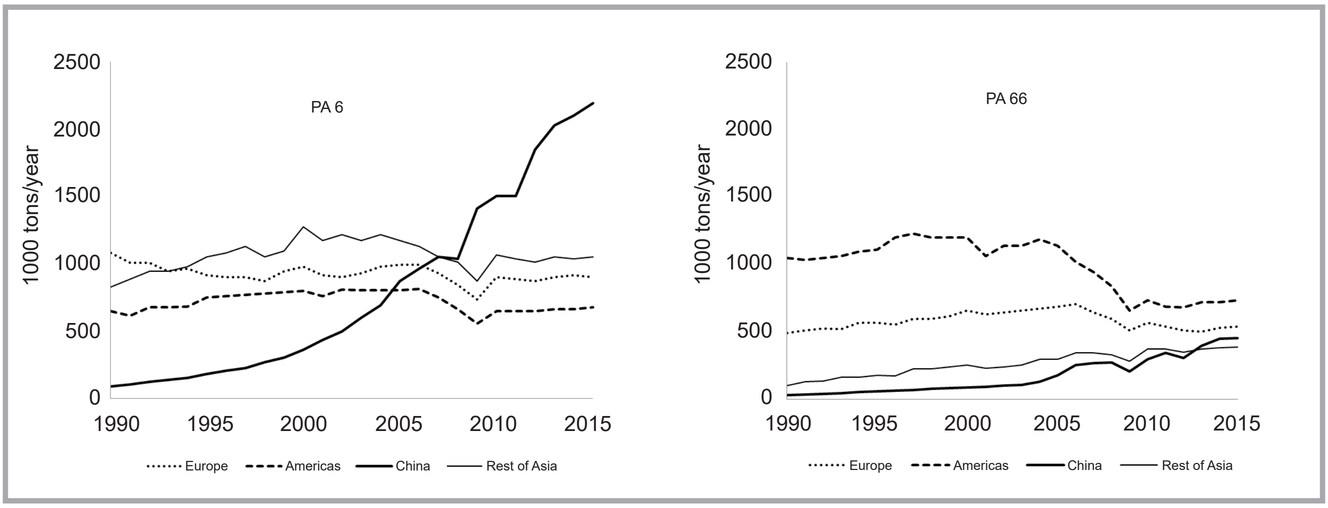

Figure 2. *Consumption of polyamides PA6 and PA66 in 1990-2015 by regions [8].*

dustrial Co. Ltd, Ube Industries Ltd. etc. [4 - 7].

The main areas of application of polyamides are:
- the production of polyamide fibres, which still consumes the largest number of polyamides globally,
- processing associated with polyamide engineering plastic,
- processing polyamides designated for films.

Consumption of polyamides

Various tendencies on the polyamide market at the turn of the century can be seen from the graphs.

Presented in ***Figure 1*** is the consumption of polyamides PA6 and PA66 in 1990 - 2015 in the areas of fibres, engineering plastics and films.

Figure 2 presents the regional breakdown of PA6 and PA66 polyamide consumption in 1990 - 2015.

The consumption of PA6 in fibres, engineering plastics and film distinctly outstripped that of PA66, used mainly in fibres and engineering plastics. The very important sector of polyamide fibres showed much slower expansion than engineering plastics and film. The tendency is particularly strong for fibre-grade PA66, whose consumption is, from the middle of the last decade, on the decrease. The American market has undoubtedly contributed to this development. On the other hand, the decrease of PA66 in the fibre sector is accompanied by increasing consumption of the material in the domain of engineering plastics.

The graphs also reveal the regress which polyamides suffered in the world-wide financial crisis which began in 2007, with various repercussions in the consecutive years. The polyamide market slackened and demand for both types of polyamides was down, necessitating a reshuffle in their production. The European scene of polyamides is a good example of the ongoing turmoil. Demand for polyamides resins in 2007 in Europe was at the level of 850 000 tons, but it dropped by about 6% in the next year. Restructuring steps were taken in consequence to improve competiveness, mainly by establishing some production facilities in Europe, for example BASF and Rhodia [9].

The big players started to invest in foreign markets, like BASF, which entered

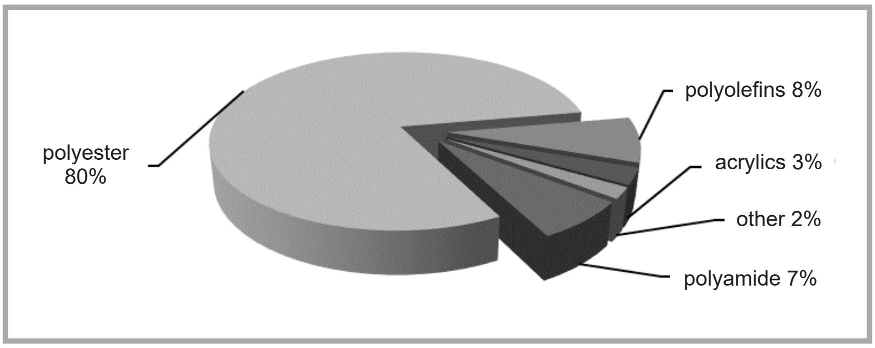

Figure 3. *World market for synthetic fibres 2014 by fibre type [17].*

China and Korea with their production. DuPont's strategy was to expand their presence in Asia; Lanxess invested in the USA, India and China, and Rhodia - in China, South Korea, India and Brasil. The American company Invista Sarl, based in Wichita, started business in Asia and both Americas. BASF nearly doubled their compounding capacities in Pudong. close to Shanghai, and in Yesan, Korea from 130 000 to 225 000 tons a year. BASF, responding to increasing demand for polyamides in the Chinese market, constructed and commissioned in 2015 in the Shanghai Chemical Industry Park, a polymerisation plant for their Ultramid® (PA6 and PA66), with a yearly capacity of 100 000 tons. Lanxess has launched a new production of PA6 and PA66 and other compounds, with a capacity of 20 000 t/y, in Porto Feliz, Brasil [10 - 13].

In the background of the poor situation in other regions of the world, China, representing the Far East region, emerges as the unquestioned leader. The Far East presently dominates the market for polyamide and related products. PA6 distinctly prevails there over PA66. The development is well illustrated with the graphs in ***Figure 2***.

The production of caprolactam is surging in the Far East as a consequence of the unprecedented increase in the demand for polyamides, dominated by PA6. As per GBI Research, New York, the global demand for caprolactam is rising steadily. It was 3.5 and 4.15 million tons in 2000 and 2011, respectively, while 6 million tons are forecasted for 2020. The share of the Far East in global caprolactam consumption shall reach nearly 70% in 2020. China has become the main world centre of caprolactam production due to the low cost of raw materials and large own demand for PA6 [14]. Despite the high domestic production, China is still a major importer of caprolactam. In recent years, imports have begun to stabilise at a similar level, but in 2011 they only increased by 0.2% to 633 thousand tons. The main supplying countries were Russia (141 thousand tons), Japan (102 thousand tons), USA (64 thousand tons), Mexico (59 thousand tons), Belorus (55 thousand tons) and Poland (32 thousand tons) [15].

A number of polyamides production centers are located in Asia, mainly in China. In the last 25 years many new production sites have been erected related with polyamides used in a variety of manufacturing. The falling imports of polyamides from Europe are being replaced with the growing production of domestic companies in China, satisfying the increasing demand. Chinese exports of the materials are focused mainly on the Asian market, while exports to Europe face difficulties due to higher quality demands. It is Asia, in contrast to Europe, where new technical and R&D centers are being opened concerned with various segments of the market, like electronics. Besides domestic companies, virtually all big players on the polyamide scene are intensifying their activity in China. Lanxess is busy in Hongkong and Wuxi, while BASF, DSM, DuPont and Solvay have started activities in Shanghai. Close cooperation with Chinese customers is the goal to better adjust production to the requirements of the local market [10, 11, 16]

At the beginning of the century, a distinct increase in the demand for polyamide materials for the production of automotive parts could be noted in the region of Eastern Europe. Many car producers located their production lines in the region due to lower costs. The branch of electronics industry also surged then mainly in Romania and Hungary. The polyamide business in Western Europe did not respond to the demands by increasing production capacity, being rather concerned with cost reduction [16]

Polyamide fibres

In 2014 polyamide fibres represented a share of 7% of the total amount of synthetic fibres produced world-wide. Polyester fibres dominate the scene with a 80% share. Polyamide fibres are facing strong competition from polyesters in many application areas. Polyesters are a universal fibre which penetrates all segments of the textile market, and moreover they are cheaper to produce than polyamides. Nonetheless polyamide fibres, with their outstanding quality, still play an important role in many demanding applications. ***Figure 3*** illustrates the world production of synthetic fibres by type.

Polyamides are processed into textile filament (NTF), industrial filament (NIF) and carpet filament (PA BCF). The list of consumers is quite long, with the main ones being producers of: underwear, decorative fabrics, fabrics for apparel, technical textiles, upholstery, floor covering, carpets, hoses, tire cord, safety belts and airbags, sewing threads, ropes, nets, sleeping bags, tarpaulins, tents etc.

Recent years have seen an increase in the production of polyamide fibres after the financial crisis in 2007 - 2008. In 2014, world production amounted to 4.55 million tons, an increase of 4,6%. In China alone the production rose by 215 thousand tons. The country is the biggest producer, with a 51% share of world production, comprising 2.24 million tons (up by 11%). Far behind were the next biggest producing countries (regions): USA 571 thousand tons (up by 1%), Taiwan 358 thousand tons (down by 5%) and Western Europe 252 thousand tons (down by 1%). The final use of polyamide fibres differs in the region: use textile and industrial yarns dominate in Asia, while BCF carpet yarns and technical textile are the prime applications in USA and Europe. After some time of stability, a downswing appeared again in the production of polyamide staple fibres, dropping to only 152 thousand tons. China with 73 thousand tons, USA with 33 000 tons and Western Europe with 30 thousand tons represent nearly 90% of global polyamide staple fibre production. In 2014 the utilisation of production capacities for polyamide continuous yarn increased on a global scale from 81% to 83%, varying from region to region: 87% in China, 85% in USA and 78% in Western Europe and Taiwan. At the same time, global capacity utilization of polyamide staple fibre was as low as 56%. [18]

The production of nylon textile filament (NTF) has remained stable over quite a long time. Even after the recession of 2008/2009 it soon returned to the pre-crisis level, which was about 1.5 million tons. The sector adapted itself well to the changing demands of the market and proved competitive against aggressive polyesters. Since 2010 there has been an increasing demand for thinner fibres for apparel, primarily for underwear. The trend is particularly manifested in China, where the demand has surged for ladies underwear and anoraks produced with NTF yarns. The company PCI Nylon forecasts a further increase in nylon textile filament (NTF) in such uses to about 2.075 million tons in 2020. Nowadays about 86% of fibres in the apparel sector are PA6 compared with a modest 14% of PA66. This proportion might be liable to change till 2020 depending upon changeable prices of raw materials. What concerns polyamide fibres for industrial filament (NIF) was the long-lasting downward trend expected after 2000 mainly in the use of tire cord. New emerging technologies and the pressure of polyester fibres in this specific area aroused concerns whether polyamide could resist the competition. However, two tendencies bolstered polyamide fibres: Firstly the demand for trucks and buses went up in developing countries; in heavy duty vehicles PA6 cord has proved to be better than the competitive polyester. Secondly an increase occurred in specialised product niches like cords, airbags, sewing threats etc. Such tendencies brought about a global increase in NIF fibre production from 1,172 million tons in 2010 to 1.349 million tons in 2015. A further increase to 1.426 million tons is expected for 2020. The share of PA6 and PA66 fibres in the production of NIF is about 60% and 40%, respectively. PCI Nylon is predicted to see a slight increase in the share of PA66 used by the end of the decade. Less favorable is the situation of polyamide fibres in the sector of carpet filament (PA BCF). There has been a definite decline in the production of these fibres compared to the end of the nineties of the previous and early years of this century. Nowadays PA BCF finds uses rather in special products. It is steadily being displaced from the commodity market by polyester BCF in the Americas and by polypropylene BCF in Europe. PA BCF production reached 0.765 million tons in 2010 and was down to 0,694 million tons in 2015. A modest increase up to the level of 0.733 million tons is envisaged for 2020. At the dawn of the century, when production of both types of PA BCF was about 1mln tons, the share of PA and PA66 was about 50% each. It has since changed to a percentage of 77% PA6 and 23% PA66. The upward trend of PA6 is expected to continue till 2020 [19].

Polyamide PA 11 is one other aliphatic fibre-grade polyamide put on the market in much lower quantities than PA6 and PA66 fibres. It has been produced for nearly half a century under the trade name of Rilsan by the French company Arkema. It is worth mentioning that polyamide is made of renewable resources; its manufacture is based on plant-derived castor oil. The oil-yielding castor plant is much easier to cultivate than cotton. In 2009 at the Techtextil Fair in Frankfurt, the Japanese company Unitika Fibre and Techcak Centre Arkema, Kioto, presented the results of their joint R&D works: a new PA11 fibre. Unitika, which manufactures the fibre, claims it is light, soft, bacteria-resistant and abrasion- resistant. It was first put to use in car mats; application is planned in shoes and bags [20].

Another group of polyamides which are used in the textile industry are aromatic polyamides called aramides. They are a very important group of industrial polymers. Special ones among other polyamides are Kevlar and Nomex, because of their possible various practical usage. Research on receiving and processing began in the laboratories of the research company Du Pont in the USA already in the forties of the previous century. The outcome of the investigations was in 1961 with the commissioning of a fibre based on poly(m-phenyleneisophtalamide) (Pm-FIFA). The name Nomex was given to the fibre. Some time later, Kevlar [poly(p-benzamide)] was put into production. Other aramides which remained in production over many years and were modified are as follows: PRD-49 by Du Pont, Fenilon, which was started in Soviet Union, MZR Duret and X-500T by Monsanto Co., AF-402 by Chemstrand, Twaron prepared by AKZO in The Netherlands and presently produced by the Japanese company Tejin, Teijinconex and Technora produced by Teijin, Arwen by Toray in Korea, New Star by Yantai Tayho, X-Fiper by SRO Group in China, and Kermel by Kermel SAS in France. Aramids are characterized by high mechanical strength, low shrinkage at elevated temperature and low creep. Aramid fibres are resistant to high temperature, organic solvents, abrasion and X-rays. The ability of self-extinguishing when in flames is quite important. The tenacity of the fibres practically does not depend upon extension. It is very important if a rapid load occurs for example in parachutes. The fibres show dimensional stability at a humidity in the range of 15 - 95%. The change in length at such conditions does not exceed 1.5%. Products made of aramid fibres are distinguished by good integrity at elevated temperature, good dynamic fatigue and dielectric properties. With all these exceptional properties, the fibres are expensive to manufacture. Priced much higher than classical polyamides, aramids are not popular in commodities; their prime use is in special materials. Aramid fibres in a variety of assortments are used in composites, ballistics, aerospace, automotive, asbestos substitute, telecommunications, and sport appliances. Braids are made of aramids to shield conductors designed for high temperature duty. Protective clothing against heat and other hazards is also one of the application areas. DuPont has prepared the production of a very strong thermal resistant paper for electrical insulation; it is made of milled sintered short Nomex fibres with some other material. The paper is designed for use in electrical engineering, the construction of transformers and loudspeakers etc.[21, 22].

Polyamide resins

The share of polyamides in the global market of engineering plastics is estimated at almost one third, as is shown in ***Figure 4*** (see page 16).

The percentages in the ***Figure 4*** represent the market in the second half of the last decade. Even in 2014, a share of 30% of polyamides in global consumption was confirmed in a report prepared by the Yano Research Institute Ltd, Tokio [23]. Based on data provided by manufacturers, the Institute forecasted a global production of engineering plastics

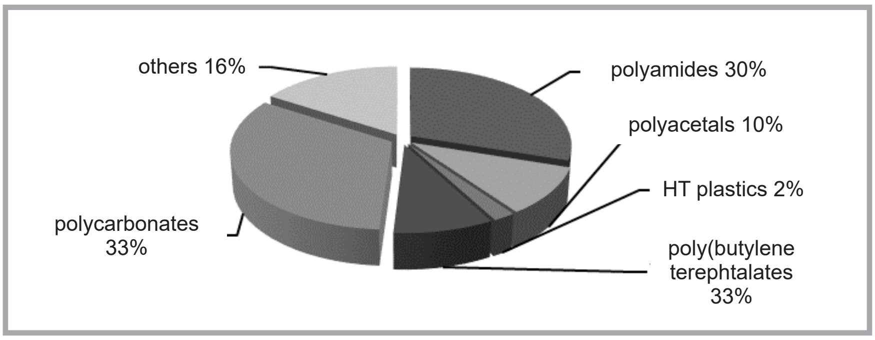

Figure 4. Global market for engineering plastics. Breakdown by type of resin.[16].

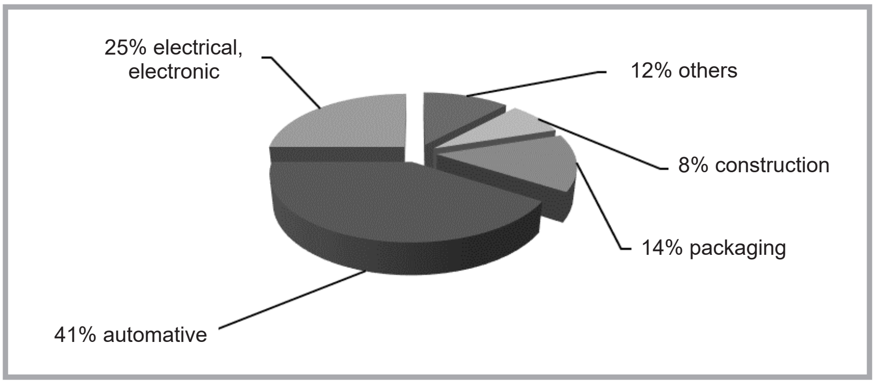

Figure 5. Use of polyamide resins in various industry branches [16].

of 8.6 million and 9 million tons for 2016 and 2017, respectively, surpassing 10 million tons in 2020 [23]. As per the Markets and Markets' report, the total value of the market for engineering plastics in 2017 shall reach a value of 76 billion US dollars [24], and according to another report of the company, it will achieve 97 billion US dollars in 2020 at growth rate of 7.6% [25] .

The demand for polyamide resins, primarily PA6 and PA66, in the manufacture of engineering plastics sector is also expected to grow. The biggest suppliers of PA6 resin are: BASF SE, DSM Engineering Plastics BV and Lanxess AG. PA66 resin is provided mainly by DuPont, Solvay (the former Rhodia SA) and BASF SE [11].

Figure 5 illustrates the estimated demand for polyamide resin in various applications. As can be seen in ***Figure 5***, the automotive sector is the largest consumer, with grow rates of polyamides higher than for other resins. The electrical/electronic branch is the second largest. The use of polyamide film dominates in the consumption pattern of the packaging segment, being used as a component of multi-layer packaging materials.

Polyamides are hard, tough and rigid materials. Having high impact abrasion and wear resistance, they are great for application in the manufacture of many construction elements. The big players of the polyamide scene like BASF SE, EMS-Chemie AG and DuPont focus their activities in a specific field not only, as before, on large-tonnage customers. They pay great attention to preparing new assortments for smaller enterprises which need highly specialised products that were previously not accessible to them. Such companies were earlier served by smaller polyamide suppliers. The manufacture and modification of polyamides for specific applications does not bring success on the market, as high quality products must be accompanied by broad extensive technical support given to customers by the producer. A good example of this has been seen recently using a computer-simulated selection of polyamide components. The new numerical models take into consideration not only the non- linear viscosity and plasticity of the compounds but also the anisotropic behaviour of short glass fibres used to reinforce thermoplastic resin; thus easing the construction of parts by e.g. optimizing the thickness of their walls. Consequently the expensive construction of prototypes may be avoided and a chance exists to predict the behaviour of materials in unfavorable conditions like high temperature or the presence of chemicals [16, 26].

The increasing consumption of resins which replace other construction materials is closely related with the general trend to reduce the weight of construction elements with maintained or improved mechanical parameters. A good example is the manufacture of lighter automobiles aimed at reduced petrol consumption. In recent years many of the metal parts in cars have been replaced with polymers and light metals like aluminum. To better illustrate the possible replacement, for example, 15 kg of polyamide is capable of replacing 30 kg of steel. Many of the polyamide elements inside a car increase stiffness at critical points. Produced from Ultramid B3WG6 CR bumpers have a construction which relieves the effects of a pedestrian/car collision. Cars are lighter and road safety is improved. Considerable amounts of polyamides are used in car parts like throttling valves, the housing of the motor chamber, and suction manifolds. The elements reveal high stability and crack resistance. Some of the elements are quite massive, reaching up to 7 kg, like the twin modules in the motors for the BMW M5 sports version. Housings for air bags are made of a PA6 Ultramid B containing 40% of glass fibres. One other type of PA66 with a 50% content of glass fibres is used to make adapters for coolers. Polyamides are resistant to chemicals like crude oil products, which has triggered attempts to prepare oil sumps, as well as petrol-, brakes- and AC- pipes with their use [16].

The chance of harnessing polyamides to meet high quality demands is the driving force of the branch. The mechanical properties of polyamide composites with glass and carbon fibres or other polyamides often match those of metals. Epic Polymers Ltd, Kaiserslautern. Germany has presented the material Strator XC, composed of PA66 and polyphtalamid (PPA) reinforced with carbon fibre, whose stiffness is comparable with magnesium and its tenacity with steel. High stiffness is also featured by another composite - Technyl Star AFX made by Solvay from PA66 with up to 60% of glass fibre. Marketed by BASF, Ultramid

D3EG12 HMG, a semi-aromatic polyamide with a 60% content of glass fibres is designed to compete with zinc and aluminum. A very high module of elasticity distinguishes the material. It has found application in the construction of backrests in the BMW i3 car. Thanks to its excellent mechanical characteristics, low water absorbance and good dimensional stability, Ultramid is replacing zinc in specific parts. A solution has been developed by the Japanese company Somic Ishikawa Inc., Hamamatsu, which was able to reduce the weight of backrests by about 50% in comparison to the metal version. The automotive industry is not the sole branch where metals are being replaced with polyamide resins. Housings for water meters are mostly made of bronze. BASF has elaborated a polyamide called Ultramid D3EG1O Aqua approved for uses in contact with potable water to replace bronze and other metals in water supply systems. Semi-aromatic polyamide has low water absorption and high stiffness, and is resistant to hydrolysis [11].

Polyamide resins applied in the electrical/electronic field must satisfy high demands for safety and flammability. Required is good insulation, high resistance to heat as well as chemical and good mechanical properties. Works are on-going to prepare new polyamide resins for this branch. A better process ability is also one of the goals. Improved melt flow behaviour provided the possibility of producing housings with thinner walls, thus saving material. The need to confer anti-flame properties emerges in the preparation of various elements and parts for industrial installations, civil engineering constructions and households. Additives used for this purpose in polyamides are compounds based on halides, antimony, phosphorus, nitrogen or hydroxides of metals. Examples of polyamide resins with reduced flammability are Ultramids made by BASF and selected Durethans by Lanxess. Ultramid A3X is a PA66 polymer with the addition of red phosphorus, which effectively reduces flammability. An admixture of long glass fibres to the polymer adds high strength at even a low temperature, and low creeping at high temperature. DuPont makes another halide-free PA66 named Zytel® FR95G25V0NH, which shows high ageing resistance at elevated temperature. Innovative in the branch of electrical/electronics are polymeric elements with integrated circuits on their surface which replace the prone-to-damage cabling systems, and ease the assembly. For that sort of application BASF has prepared the semi-crystalline, semi-aromatic temperature-resistant Ultramid T 4381 LDS with a laser-formed structure [10, 11, 16, 26].

In the packaging business polyamides are primarily used in the form of film. Single polyamide film is rarely used, but a common application is in multilayer, transparent foil combined with other polymeric film of polyethylene, polypropylene or poly(vinyl alcohol). In such films for the packing of perishable alimentary products like cheese, meat etc, the polyamide layer provides a good barrier that prevents oxygen penetration as well as loss of humidity and aroma. The polyamide component adds stability to the multilayer structure. The present trend in households of using small packaging units for ready-made food is expected to bolster the demand for polyamides in film manufacture in the coming years [16].

Polyamide resins also find use in building. Simple stuff like door handles, pins and handrails are often made of PA, yet more advanced products are also an outlet, like special long-life, UV-resistant, weatherproof fastening elements. Photovoltaics have opened a new avenue of application for polyamides. Several new grades of polyamides have recently been approved for use in the construction of photovoltaic modules, for example Ultramid A3X2G7, Ultramid A3XZG5 and Ultramid B High Speed [10, 16].

The list of other possible applications for polyamides is quite long, with the following being a few examples of established, common uses: gear wheels, machinery parts, pressure pipes, wheels for prams, fishing lines, monofilaments for brushes, strings for tennis rockets, aerosol containers, blood bags, syringe catheters and many more. Extensive research is devoted to finding new material combinations and new fields of use, which demonstrates the great versatility of these materials, whose properties can be very successfully adapted to specific requirements in other areas. An example might be the interest shown in polyamides by the furniture designers Bouroullec brothers, who designed the so-called "Chairs plant". Another example is the design of the design studio ding3000 so-called "Joined cutlery", based on polyamide Ultramid A3EG6FC, which has been approved for contact with food [10].

Most of the examples of polyamide materials above point at physically or chemically modified PA6 and PA66. Other polyamides also come into play. Semi-aromatic polyamides based on poly(phtalamide) made by DuPont de Nemours, Solvay and Ems-Chemie AG are used in the automotive industry. Long-chain polyamides like PA12 produced by Evonik Industries AG and EMS-Chemie AG [11] are replacing PA 6 and PA66 in products in which durability and dimensional stability in varying weather conditions are the challenge. They are used mainly in situations requiring very specific characteristics and in situations where their characteristics and wide area of usage is more important than the price. The same is true of another group called **bio-polyamides**, which are based on natural renewable resources. The dominating polymer is the long-chain polyamide PA11. The largest producer of the material is Arkema SA, which derives it from castor oil. Other representatives in the group are polyamides PA 6,10, PA 6,12, PA10,10 and PA10,12, supplied primarily by DuPont, Evonik Industries AG, EMS-Grivory, Suzhou Hipro and BASF SE. The polymers are an interesting complement to the classical crude-oil-derived polyamides. In some specific applications they compete with the classical ones, while in other niche uses they target high quality demands, surpassing PA6 and PA66. Worth mentioning is the environmental aspect of the use of bio-polyamides. Both the material and production technologies are environment-friendly. Prices higher in comparison to crude-oil-derived polymers presently pose a barrier for wider use, which may change in the future with the rising prices of the classical materials and tax relief, privileging natural materials. Their increasing use will certainly depend upon interesting properties and new possible application areas. The emerging possibility of blending nature-derived polymers with fossil-derived ones may bring such a chance. The blending may also lead to favorable price/ output/ quality proportions [27].

Summary

The polyamide market is a mature market and well developed. We can observe growth tendencies in terms of its global size as well as predicted production growth in future years. In spite of the fact that polyamides can be used in classical applications such as the production of chemical fibres, for many years there have been noticed big growth tendencies concerning the demand for polyamide resins. The polyamide resin sector will be much bigger not only in terms of its size, but also its quality. In the coming years, more and more polyamide resins based on various polyamides will form an integrated part of various, individual technical and technological solutions.

References

1. Albrecht W, Chrzczonowicz S, Czternastek W, Włodarczyk M and Ziabicki A. *Poliamidy*, WNT Warszawa, 1964.
2. *Chemical Fiber International* 2015; 3: 129.
3. PCI Research GmbH, "Yellow Book" World PA6 & PA66 Supply/Demand Report, 2016
4. Ceresana Market Intelligence. Consulting, Report *Market Study: Polyamide – PA6 & PA66*.
5. Markets and Markets, Report Polyamide Market by Type (PA 6, PA 66, Bio-Based & Specialty), by Application (Automotive, Films & Coatings, Industrial/ Machineries, Consumer Goods & Appliances, Fibers & Textiles, and Others), by Process, and by Region-Global Trends and Forecast to 2020, http://www.marketsandmarkets.com /PressReleases/ global-nylon.asp
6. Global Industry Analysts Inc., Report *Nylon – A global strategic business repor*",
7. http://www.prweb.com/releases/nylon_market/nylon_6_market/prweb3832954.htm
8. PR Newswire Report, Bio-Polyamide, Specialty Polyamide & Precursors Market by Type (PA 6, PA 66, PA 10, PA 11, PA 12 & Others), by Precursor (CPL, ADA & HDMA), by Material (Fiber & Plastics) & Application (Textile, Automotive, E&E & Others) - Global Trends & Forecasts to 2019, http://www.marketsandmarkets.com/ Market-Reports/polyamide-precursors-market-29328940.html
9. *Chemical Fiber International* 2015; 1: 28
10. AWJ Consulting, Report *The Polyamide Market in Europe*, September 2010.
11. Bluhm R at al., Polyamides (PA), Dynamic Development. *Kunststoffe International* 2011; 10: 27-32.
12. Scheibitz M, Cremer J, Polyamides (PA), Problem Solver for Lightweight Construction and Numerous Highly-Specialized Cases. *Kunststoffe International* 2014; 10: 34-39.
13. *Chemical Fiber International* 2013; 3: 148.
14. https://www.basf.com/en/company/news-and-media/news-releases/2015/05/p-15-222.html,
15. Chemical Fiber International 2013, 1: 24.
16. Chemical Fiber International 2012, 2: 74.
17. Rosenau B, Polyamides (PA), Growth in PA Compounds. *Kunststoffe International* 2007; 10: 66-70.
18. *Man-Made Fiber Year Book* 2015; 24.
19. *Man-Made Fiber Year Book* 2015; 25.
20. *Man-Made Fiber Year Book* 2015; 27.
21. Advert materials of Arkema Co ‚New high performance synthetic fiber of 100% vegetable origin produced from Rilsan® PA11.
22. Hałasa E E, Heneczkowski M. Aromatic Polyamides Part 1 (in Polish) *Polimery* 1998; 144.
23. Hałasa F E, Heneczkowski M. Aromatic Polyamides Part 2 (in Polish) *Polimery* 1998, 209.
24. Yano Research Institute Ltd., Report *Global Engineering Plastics Market: Key Research Findings 2014.*
25. Markets and Markets, Report *Global Engineering Plastics Market Worth $76,823.4 Million by 2017*, http://www.prnewswire.com/news-releases/marketsandmarkets-global-engineering-plastics-market-worth-768234-million-by-2017-160490825.html
26. MarketsandMarkets, Report *Engineering Plastics Market by Type (PC, ABS, PET & PBT, POM, Fluoropolymers and Others), Application (Automotive & Transport, Industrial & Machinery, Packaging, Consumer Appliances, and Others) - Global Forecast to 2020,* http://www.marketsandmarkets.com/ Market-Reports/engineering -plastics-market-687.html
27. Papers from Du Pont Fakuma Fair 2014: Werkstoffentwicklungen und anwendungstechnische Zusammenarbeit als Antrieb für Innovationen.
28. Kabasci S. *Bio-Based Plastics Material and Applications,* 275-293, Wiley 2014.

Received 29.07.2015 Reviewed 02.11.2016